FM Receiver

Superheterodyne FM Receivers

- The standard broadcast FM receiver is basically the same as the AM receiver up through the IF amplifier.
- The main difference between an FM receiver and an AM receiver, other than the frequency band, is the method used to recover the audio signal from the modulated IF.

Difference Between AM and FM Spectrum

- AM and FM have different radio frequency (RF) spectrum ranges:

– AM: 540 kHz – 1600 kHz

– FM: 88 MHz – 108 MHz

- Therefore, two IF frequencies

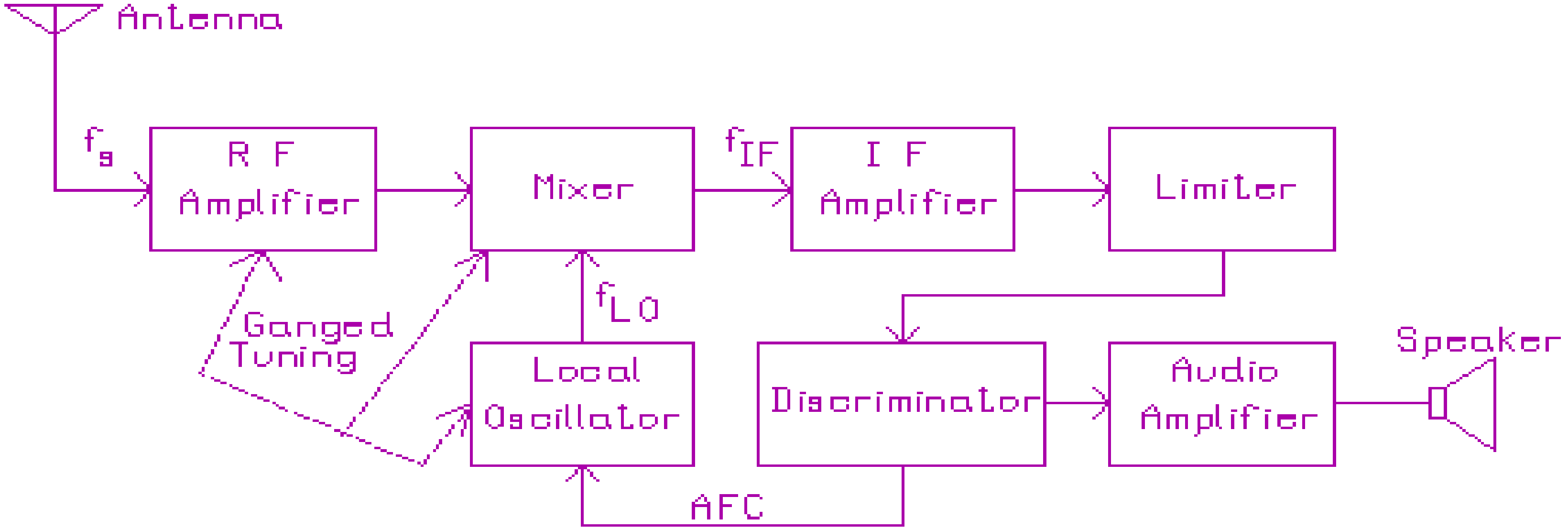
– AM: 455 kHz

– FM: 10.7 MHz

For AM radio, each station occupies a maximum bandwidth of 10k Hz

- Carrier spacing is 10 kHz
- For FM radio, each station occupies a bandwidth of 200 kHz, and therefore the carrier spacing is 200 kHz

FM Receiver Block Diagram

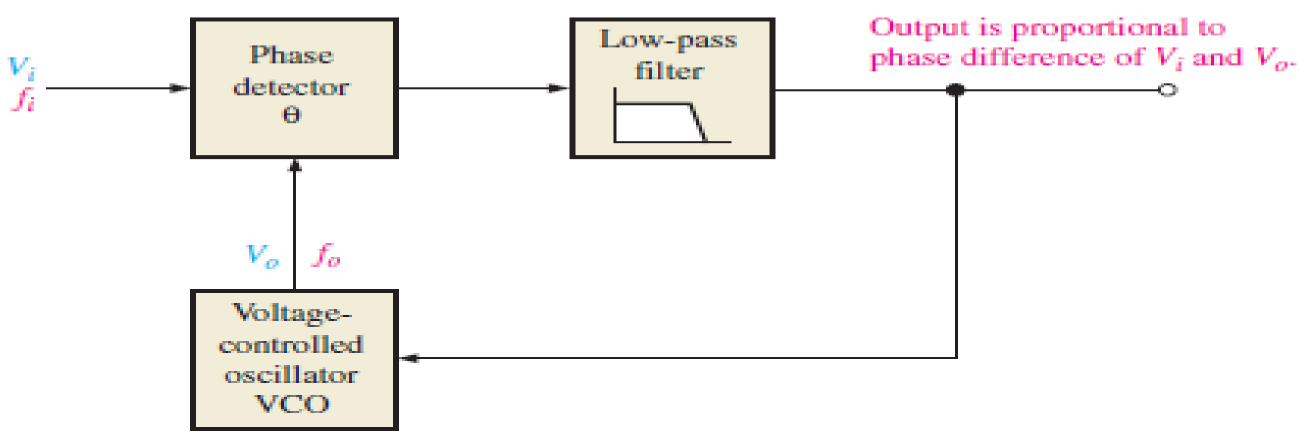


FM Demodulators

- There are several methods for demodulating an FM signal. These include:
- Phase-locked loop demodulation.
- slope detection,
- phase-shift discrimination.
- Ratio detection.
- Quadrature detection.

The Phase-Locked Loop (PLL)

- PLLs are used in a wide variety of communications applications, which include TV receivers, modems, and data synchronizers.
- The **phase-locked loop (PLL)** is a feedback circuit consisting of a phase detector, a low-pass filter, and a voltage-controlled oscillator (VCO).



The Phase-Locked Loop (PLL)

- The PLL is capable of locking onto or synchronizing with an incoming signal.
- When the phase of the incoming signal changes, indicating a change in frequency, the phase detector’s output increases or decreases just enough to keep the VCO frequency the same as the frequency of the incoming signal.

Basic PLL block diagram.

The Phase Detector

The phase-detector circuit in a PLL is basically a linear multiplier. The following analysis illustrates how it works in a PLL application. The incoming signal, V_i, and the VCO signal, V_o, applied to the phase detector can be expressed as

$$v_i = V_i \sin(2\pi f_i t + \theta_i)$$

$$v_o = V_o \sin(2\pi f_o t + \theta_o)$$

where θ_i and θ_o are the relative phase angles of the two signals. The phase detector multiplies these two signals and produces a sum and difference frequency output, V_d, as follows:

$$
\begin{aligned}
V_d &= V_i \sin(2\pi f_i t + \theta_i) \times V_o \sin(2\pi f_o t + \theta_o) \\
&= \frac{V_i V_o}{2} \cos[(2\pi f_i t + \theta_i) - (2\pi f_o t + \theta_o)] - \frac{V_i V_o}{2} \cos[(2\pi f_i t + \theta_i) + (2\pi f_o t + \theta_o)]
\end{aligned}
$$

When the PLL is locked,

$$f_i = f_o$$

and

$$2\pi f_i t = 2\pi f_o t$$

Therefore, the detector output voltage is

$$V_d = \frac{V_i V_o}{2}[\cos(\theta_i - \theta_o) - \cos(4\pi f_i t + \theta_i + \theta_o)]$$

The second cosine term in the above equation is a second harmonic term ($2 \times 2\pi f_i t$) and is filtered out by the low-pass filter.

The control voltage on the output of the filter is expressed as

$$\boldsymbol{V_c = \frac{V_i V_o}{2} \cos \theta_e}$$

where the phase error $\theta_e = \theta_i - \theta_o$. The filter output voltage is proportional to the phase difference between the incoming signal and the VCO signal and is used as the control volt-

The Voltage-Controlled Oscillator (VCO)

Voltage-controlled oscillators can take many forms. A VCO can be some type of *LC* or crystal oscillator, or it can be some type of *RC* oscillator or multivibrator. No matter the exact type, most VCOs employed in PLLs operate on the principle of *variable reactance* using the varactor diode as a voltage-variable capacitor.

The capacitance of a varactor diode varies inversely with reverse-bias voltage. The capacitance decreases as reverse voltage increases and vice versa.

In a PLL, the control voltage fed back to the VCO is applied as a reverse-bias voltage to the varactor diode within the VCO. The frequency of oscillation is inversely related to capacitance for an *RC* type oscillator by the formula

$$f_o = \frac{1}{2\pi RC}$$

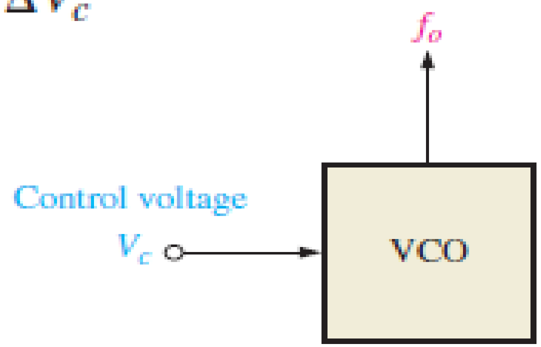
and for an *LC* type oscillator by the formula

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

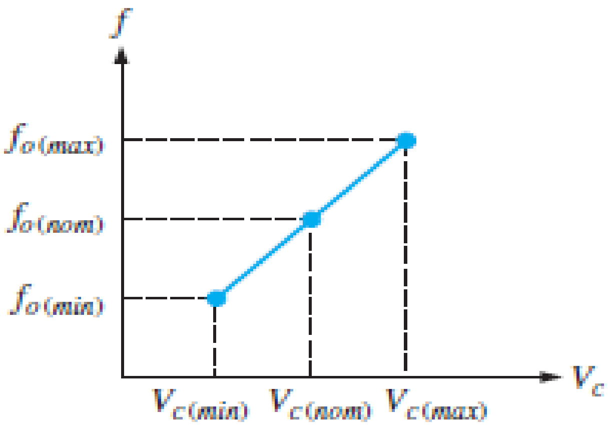
The Voltage-Controlled Oscillator (VCO)

- Capacitance decreases as reverse voltage (control voltage) increases.
- Therefore, an increase in control voltage to the VCO causes an increase in frequency and vice versa.
- Basic VCO operation is illustrated in Figure

$$K = \frac{\Delta f_o}{\Delta V_c}$$



(a)



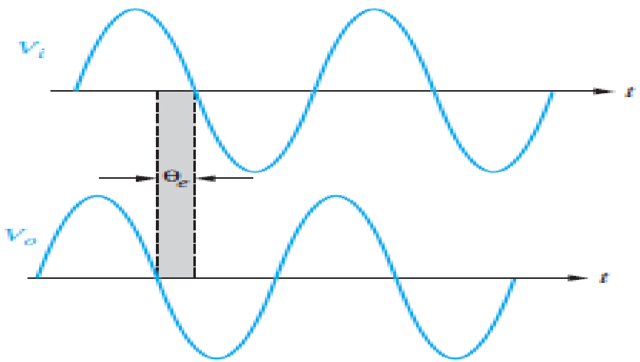
(b)

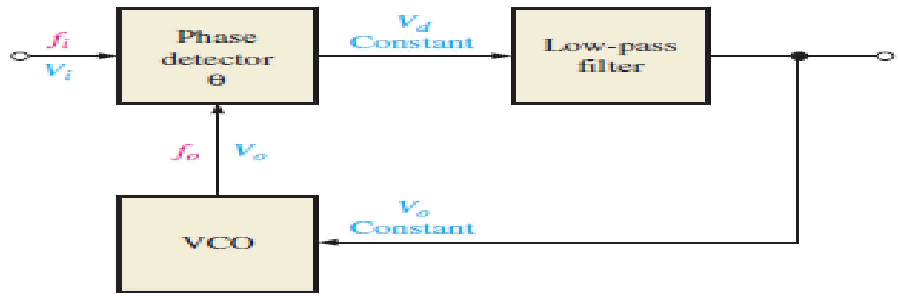
- Figure below shows the PLL and two sinusoidal signals of the same frequency but with a phase difference, For this condition the PLL is in lock and the VCO control voltage is

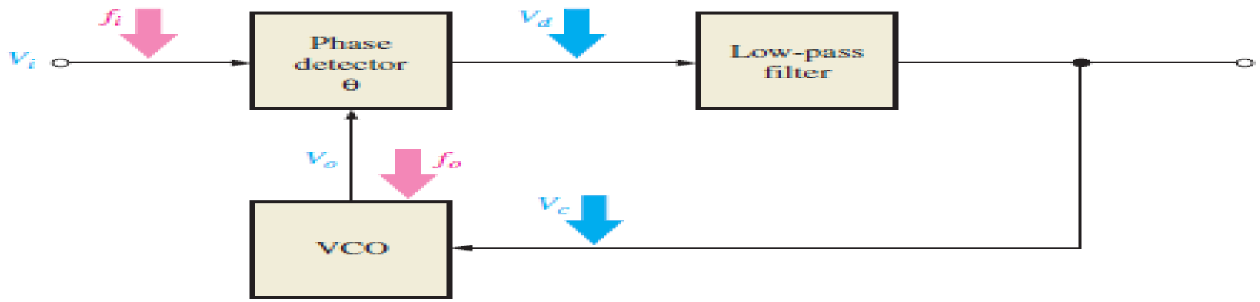
constant.

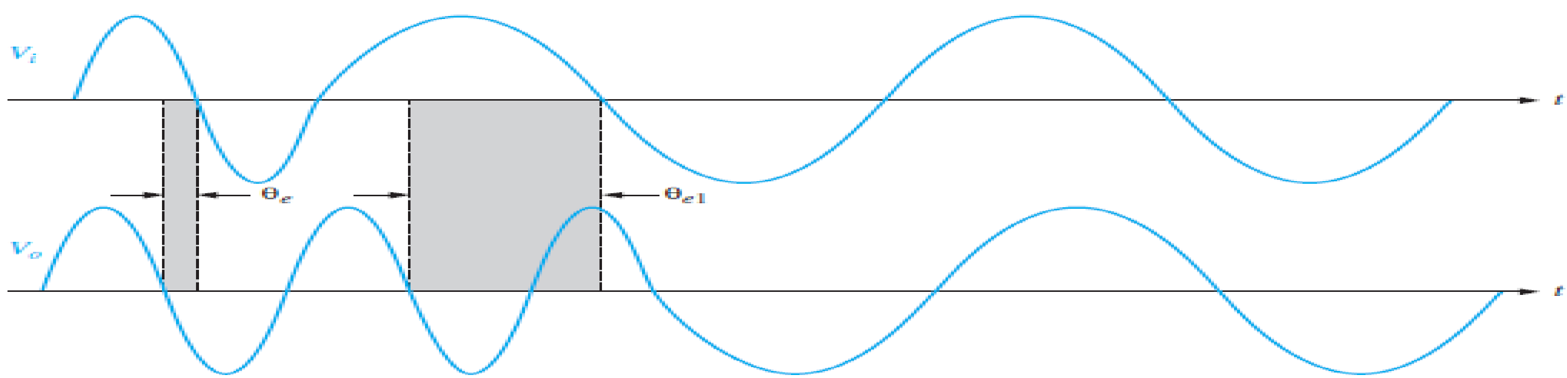
- If *f_i* decreases, θ_e increases to as illustrated in the Figure This increase in phase error is sensed by the phase detector causing the VCO control voltage to decrease, thus decreasing *fo* until *fo* = *fi* and keeping the PLL in lock.

PLL action when *fi* decreases.

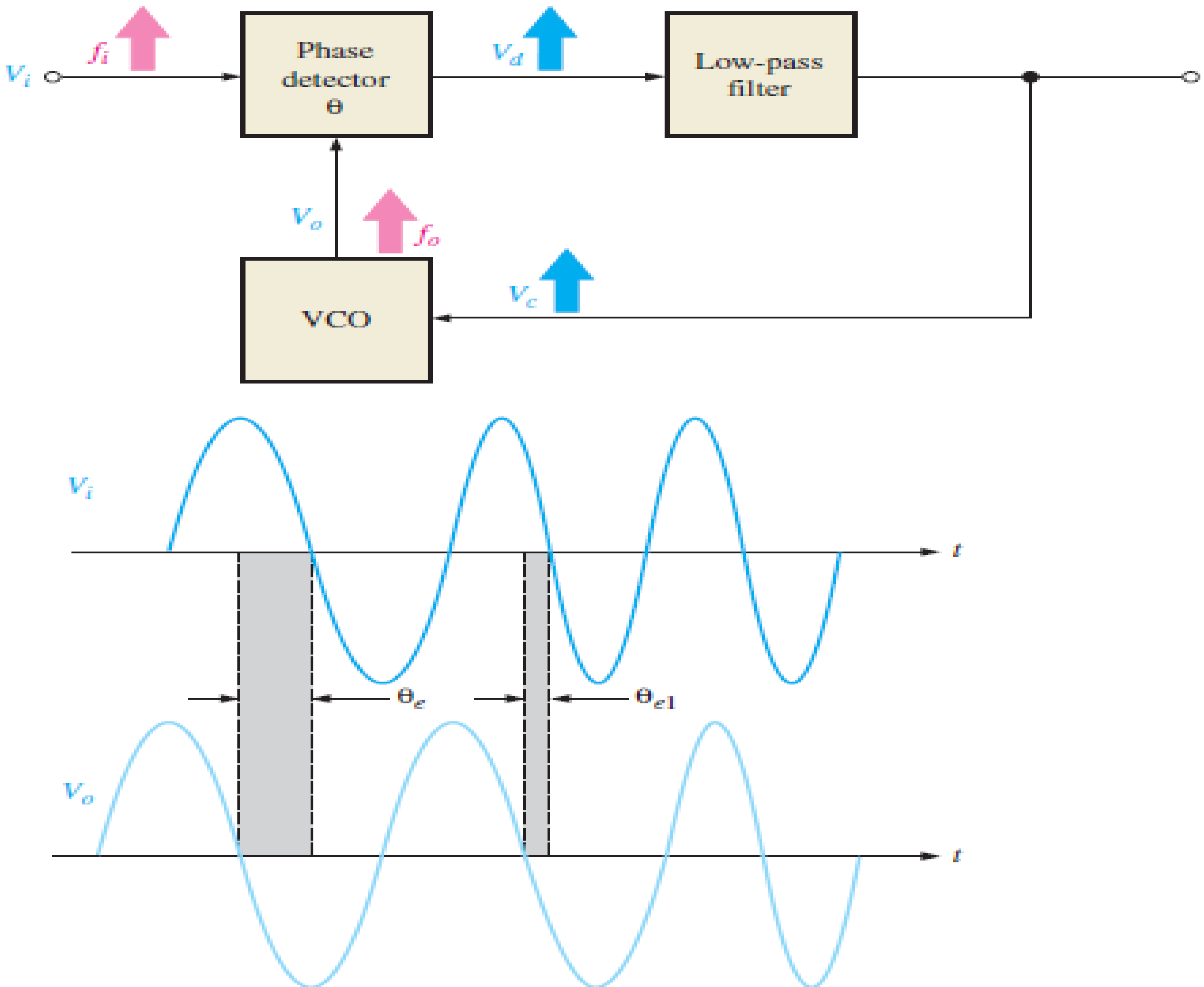








PLL action when *fi* increases.



Lock Range Once the PLL is locked, it will track frequency changes in the incoming signal. The range of frequencies over which the PLL can maintain lock is called the **lock range** or tracking range. Limitations on the hold-in range are the maximum frequency deviations of the VCO and the output limits of the phase detector. The hold-in range is

Capture Range Assuming the PLL is not in lock, the range of frequencies over which it can acquire lock with an incoming signal is called the **capture range**.

The lock range is given by

$$f_{lock} = \pm \frac{8f_o}{V_{CC}}$$

where V_{CC} is the total voltage between the positive and negative dc supply voltage terminals.